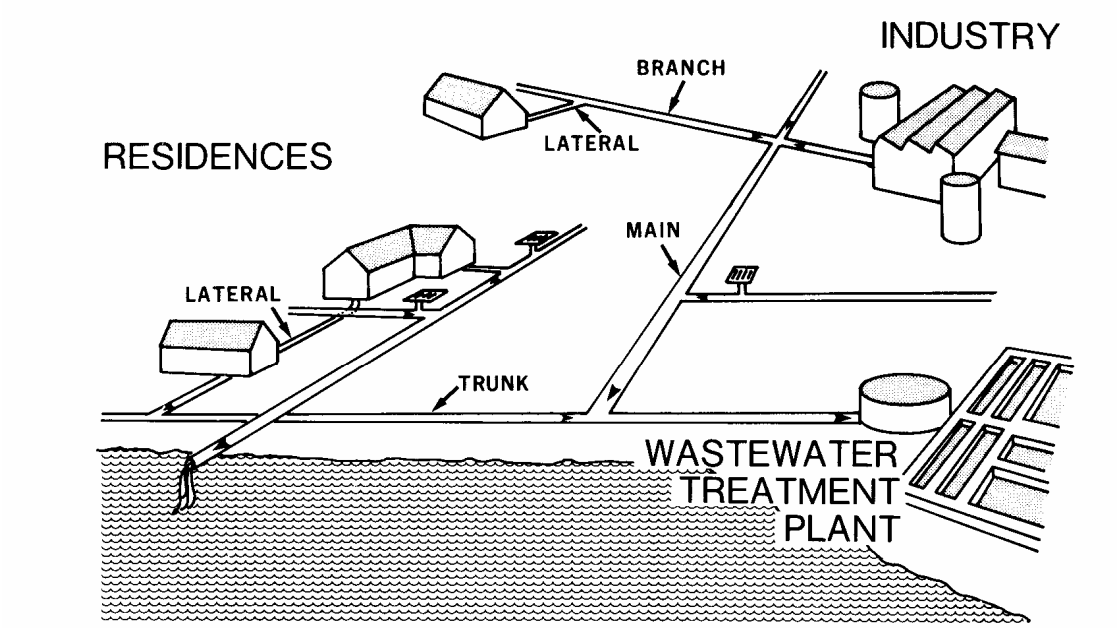
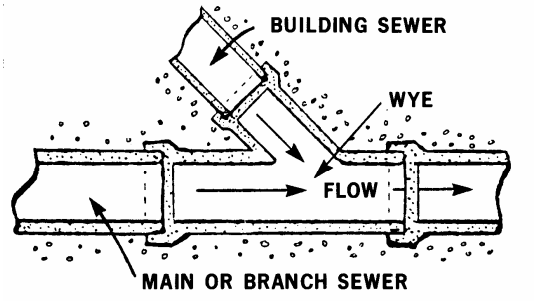
WASTEWATER COLLECTION SYSTEMS

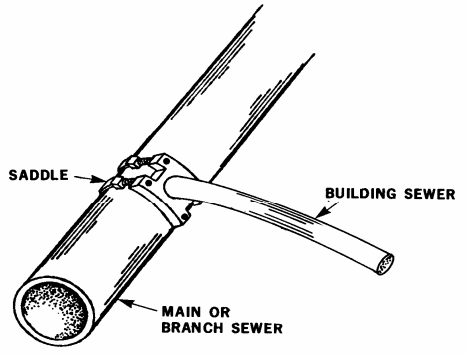
Wastewater collection systems are responsible for collection and transmission of liquid wastes to a central treatment facility. Like a distribution system for water supply, the collection system resembles a tree that branches out from the treatment plant to collect the wastewater from individuals. Wastewater from individual homes enters the collection system from a service line. These services attach to the lateral with a wye connection or a tap and saddle connection. Branch lines or laterals usually run down the street, collecting the flow from individual services. They, like tributaries in a watershed, flow into larger lines called mains. Mains carry the flow into the largest lines in the system, called trunk lines. A trunk line is a transmission line that doesn't have any mains branching off of it. It is the pipe that brings water into the treatment plant. This line is also referred to as the outfall.



Wastewater Collection System



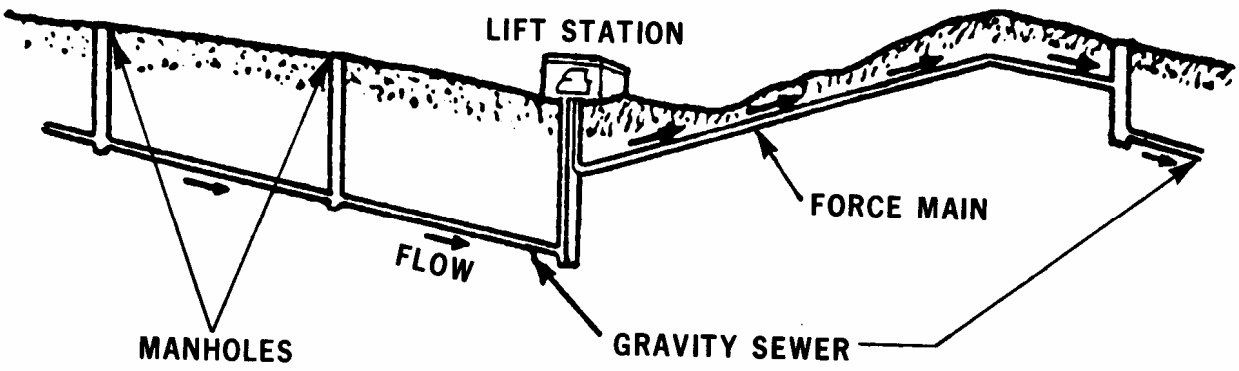
Wye Service Connection



Tap & Saddle Service Connection

Manholes are installed in sewer lines whenever there is an intersection, change of direction, or change the in elevation or slope of a line. They are needed to provide access to the system for cleaning, inspection, and clearing stoppages. Although they should be large enough for operators to enter and work in, they can contain hazardous atmospheres that can endanger workers. With today's modern equipment most work done on sewer lines can be accomplished without entering the manhole and putting workers at risk.

Collection lines are installed with a downhill slope that allows the flow to move through most of the system by gravity. This minimizes the amount of pumping that must occur to get the water to the treatment plant. The slope must be adequate to maintain at least 2 feet per second velocities in the line. When the sewer lines reach a certain depth, the flow must be lifted back to near the surface so that it can begin flowing by gravity again. Lift stations are built whenever wastewater must be pumped to a higher altitude, whether it's to lift water up so that it can gravity flow or to pump it over a rise or hill.



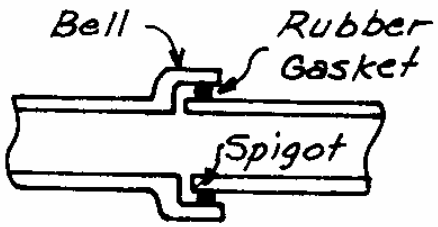
Lift Station and Force Main

Collection systems must be designed to handle peak flow conditions. The size of the pipe, the type of pipe, and the downhill grade of the line determine the amount of flow that a line can handle. The average per capita flow that is used to size the system is usually about 100 gallons/person/day. Infiltration and inflow are also concerns when designing a collection system. Infiltration occurs when groundwater enters the system through broken pipe or leaking joints in wet weather. Inflow enters the system directly and may come from runoff that floods streets, entering through submerged manhole covers, or illegal service connections that direct storm flows into the system. Exfiltration occurs when sewage leaks out the pipe into the surrounding soil. Systems can gain some control over inflow and infiltration by the creation of local sewer use ordinances.

Sanitary sewers carry wastewater to treatment facilities. Storm sewers carry storm water runoff to the receiving body. Although storm water is usually low in BOD, the initial flow can contain relatively high concentration of suspended solids in the form of grit and dirt.

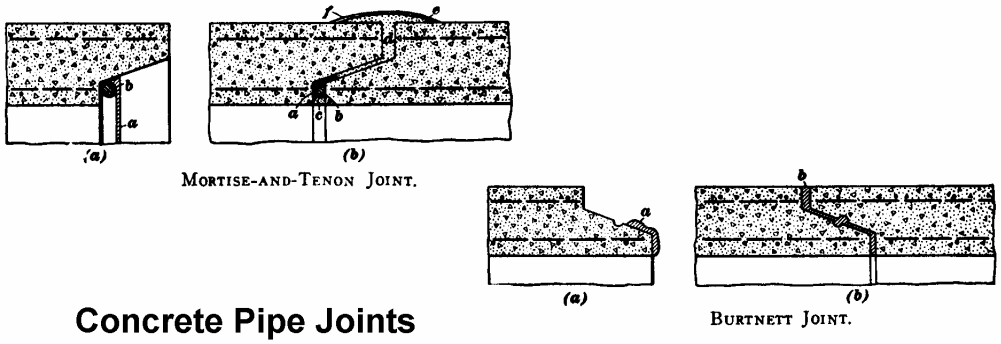
WASTEWATER PIPING

The most common type of wastewater piping is vitrified clay pipe or VCP. It is made of fired clay and is constructed with bell and spigot connections. The spigot end of the pipe will have a rubber gasket, like an O-ring, bonded to the outside of the pipe. It creates a watertight seal for the joint. VCP has sufficient strength to withstand most trench loads and is almost impervious to corrosion caused by acids that form when sewer gases are generated. VCP is available from 4" to 36" in diameter. It is very heavy in sizes above 18".



Bell & Spigot Joint

Reinforced concrete pipe, or RCP, is used for larger lines from 18" to 60" in diameter. It is lighter than VCP at these sizes. Concrete pipes can have bell and spigot connections or mortise and tenon joints that fit together and are sealed with rubber gaskets or bitumastic compounds. The problem with concrete pipe is corrosion of the pipe crown area (top inside of the pipe) from sewer gases and organic acids.



Concrete Pipe Joints

Cast iron pipe (CIP) and ductile iron pipes (DIP) are not used often in collection systems, but have specific applications. They are used in areas where high trench loading exists like crossing under a railroad track or a dirt road that carries heavy equipment. Iron pipe is also used for inverted syphons where collection lines run under roadbeds or streams. Iron pipe is also subject to corrosion from sewer gases.

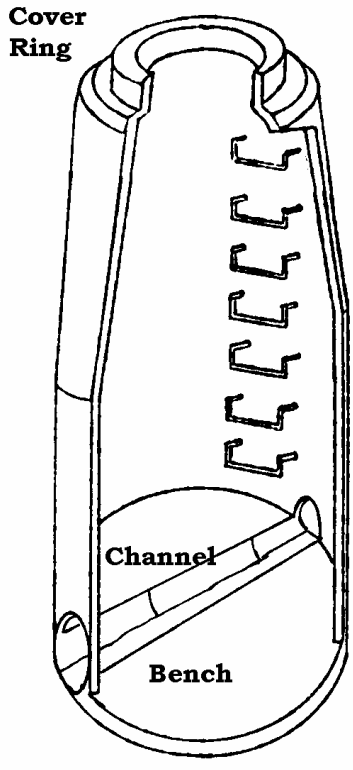
Acrylonitrile butadiene styrene (ABS) pipe is made from plastic. It is lightweight and flexible. It is impervious to corrosion from sewer gases, acids and bases, and inorganic salts found in wastewater. It is softened by petroleum products, which are not normally found in domestic wastewater. It can't withstand heavy trench loading and can be flattened out into an oval shape that can make normal cleaning and inspection impossible. Polyvinyl chloride (PVC) piping is also lightweight and easy to install. Petroleum products do not affect it, but trench loading is still a problem.

MANHOLES, CLEANOUTS, AND INVERTED SIPHONS

Manholes should be spaced no more than 400 feet apart in straight runs of pipe. The limiting factor is that most cleaning equipment will not have more than 400-500 feet of rod or hose on the unit. They should also be installed anywhere pipes intersect or there is a change of direction or grade. They are normally constructed of either brick or pre-formed concrete cylinders. In areas where groundwater infiltration is a problem, they can be made from fiberglass reinforced polyester rings.

A base is poured that is at least 1 foot larger in diameter than the manhole rings to support the loads that occur when vehicles drive over the manhole cover. If it cannot support the load and the cover is compressed, the piping at the manhole may be damaged. Most manhole rings are at least 4 feet in diameter to allow access and room to work inside them. They are stacked on the base and grouted to prevent infiltration.

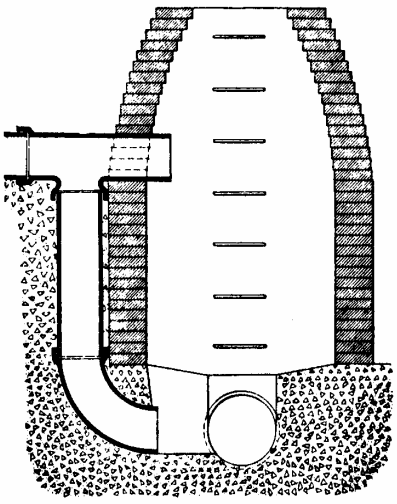
An eccentric cone is placed on top of these rings that narrows the opening to the size of a manhole cover. An iron cover ring is then placed on top of the cone and the cover sets inside the ring. The ring and cover must be flush with the pavement so that it doesn't present a hazard to traffic. When streets are re-paved adjustment rings are used to bring the cover back up to grade. For distances of more than 6 inches, the cone ring should be removed and additional manholes rings added.



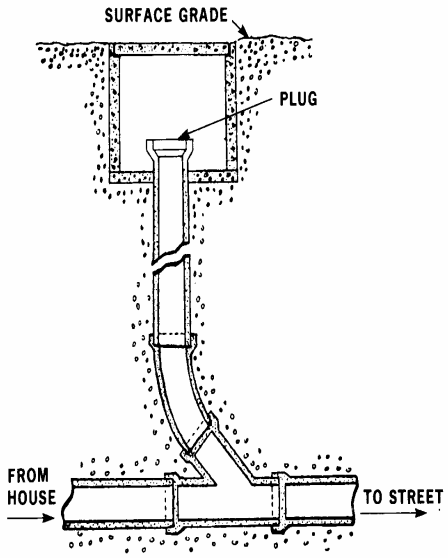
Typical Manhole

The base of the manhole is formed into a channel and bench. The bench on either side of the channel is flat but sloped toward the channel to insure drainage. Covers with multiple holes should not be used in low-lying areas or where streets are not properly crowned to drain runoff away from the covers.

Drop manholes are used when sewer lines intersect at different elevations or when velocities in the line get too high. When velocities approach 10 feet per second, the scouring action of grit in the flow can erode the pipe.

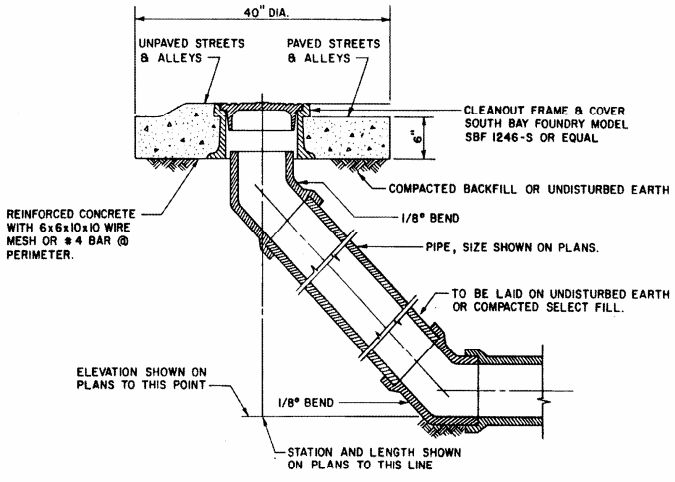


Drop Manhole



Sewer Service Cleanout

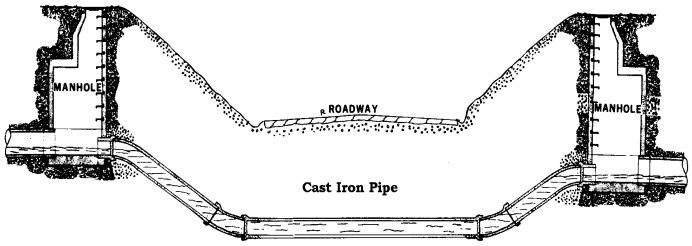
Cleanouts are installed on service lines and sometimes at ends of laterals, in place of a manhole. They are installed for economic reasons. They cost 1/6 as much as a manhole. They allow access for cleaning equipment.



Sewer Main Cleanout

INVERTED SIPHON

Inverted siphons are used when the line must drop below grade to pass under an obstacle like a roadway, streambed, or arroyo. Inverted siphons are difficult to clean and rely on high velocities to remove grit and debris that accumulates during low flow conditions. The siphon will be a smaller diameter pipe. The smaller pipe will need to create a velocity of over 2 fps at low flows.



Inverted Siphon

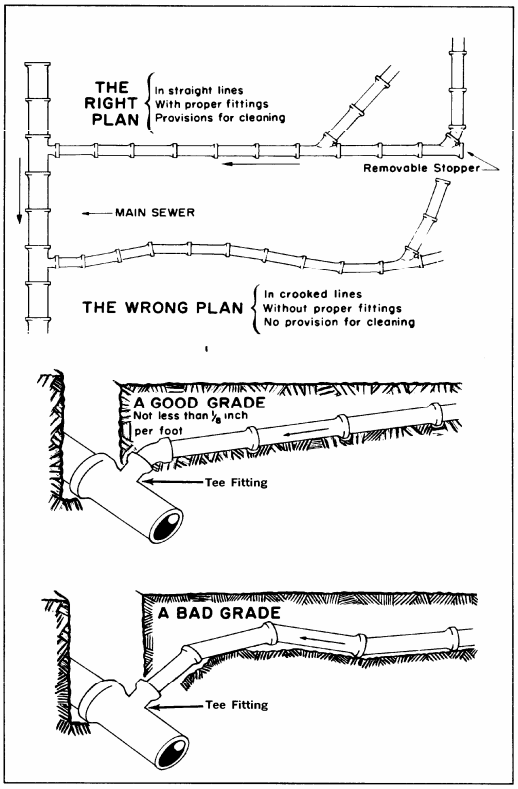
SERVICES

Service lines and connections from residential customers must be properly installed. Improper installation can result in backups in the customer's plumbing or stoppages in the main. Service lines must slope at least 1% or 1/8" per foot so that the velocity is sufficient to carry solids to the main.

Crooked services or services with uneven grades are difficult to clean and cause debris to collect in the line. Bad joints that leak can be a source of infiltration and root intrusion into the service and the main.

Service connections are made using a pipe "wye" connection, installed when the main is laid, or a saddle and tap into an existing line. This method provides the best possible structural integrity in the line and prevents obstruction that can be caused by intrusion.

Saddle taps are attached to the main by drilling a hole in the main and attaching a saddle. The saddle has a connection for the service line that will prevent intrusion into the pipe. When a tap hole is drilled, it is important to remove the circular piece of the main, known as a coupon, so that it doesn't cause a stoppage downstream. The tapping saddle should be covered with a mound of concrete for support.



If the service line is simply inserted into a hole in the main, it will intrude into the line and increase the possibility of creating a stoppage. It will also create a problem for cleaning equipment. The connection will probably leak, allowing root intrusion and infiltration.

COLLECTION SYSTEM CONSTRUCTION

Sewer lines are usually laid deeper than water lines. They can run as deep as 30 feet before lift stations are needed. This means that trenching and shoring issues are much more complex than when trenching for water lines. Trenching and shoring safety issues are addressed in Chapter 16. Some deep trenches must have shoring systems that are designed by an engineer. Prior to digging always get other utilities to spot their lines first. Most states have a blue stake or one-call system established for utility location. Traffic control must be established and area residents should be notified of construction and any interruption of service that could result before excavation begins.

Wastewater collection systems are designed to have water flow downhill by gravity. The only time pumps are used is when the flow needs to be lifted so it can flow by gravity again. A downhill grade or slope must be established in order to maintain a certain velocity in the piping. Sewer lines are more difficult to install because the pipe must be laid straight and the slope of the pipe must remain constant. The line must be straight so cleaning equipment can pass through it. Curved piping runs also increase possibility of solids settling in the lines. Changes in slope or grade can also lead to solids settling in the low spots.

Many operators are not directly involved in the installation of collection system piping. A knowledge of the proper procedures for correctly and safely installing these lines is important because operators may be responsible for the inspection of a contractor's work or making repairs on existing lines.

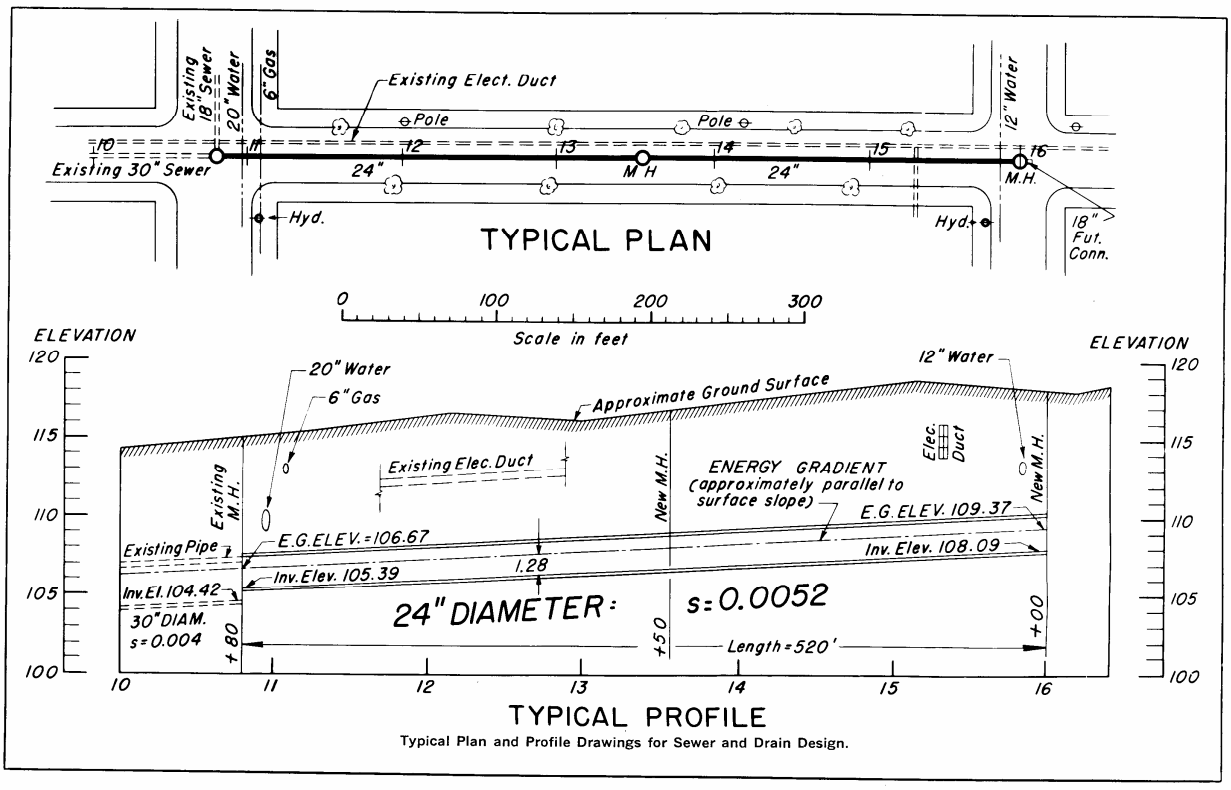
HANDLING PIPE

Water piping should always be handled with care. Although it is inspected before it leaves the factory, damage can occur during shipment. Always check all pipe materials, gaskets and fittings before accepting a shipment of pipe. Vitrified clay pipe is checked by tapping sections lightly with a hammer. A pipe that is not cracked will make a faint ringing sound. Piping should be unloaded in the area where it is to be installed. It is usually placed along the side of the trench. It should never be moved using a backhoe bucket or blade. Proper rigging and slings are needed to safely move heavy iron or concrete cylinder pipe sections. Store all gaskets and fittings in an area where they will not become damaged or contaminated.

EXCAVATIONS AND UTILITY LOCATION

It is important to remember that the collection system is not the only utility located in or near the street. The statewide “Blue Stake” number should be called to get the other utilities spotted before the trenching operations begin. Failure to request line spots for other utilities will make the system responsible for any loss of service or product and the cost of repair if they are hit.

Excavations for sewer lines must be dug to grade. The depth of the line may vary with changes in surface contours. Plan and profile maps are used to determine the correct location and depth of the line. A plan view is a view from above. It is used to determine the location of the line and major components of the system. These are put together to create the section maps that maintenance crews use for line and manhole location.



A profile view is a side view showing the soil contours and depth of the line. Distances are identified from a reference point as stations. The section of pipe shown here begins at 10 +80 (or 1080 feet from reference) and ends at 16 +00 (or 1600 feet). It is 520 feet long.

PIPING GRADES

The downhill slope of the pipe must be adequate to maintain a 2 foot per second velocity. At 2 fps, the grit and heavy inorganic solids will not settle out in the lines and cause stoppages. Odor and corrosion problems are also more prevalent in lines where slopes are not adequate to maintain minimum velocities.

The slope of a line is calculated by dividing the rise (or drop) by the run or length of the line. For instance, if a run of pipe is 400 feet long and it drops 1 foot, the rise over the run is 1/400 or 0.0025. It would also be a 0.25% slope. It is important to make sure the grade is constant.

There should not be deviation above or below the grade line. The pipe is laid so that the invert, or inside bottom of the pipe, is at the proper slope. On a profile map, it is identified as the invert elevation (Inv. Elev.). The inside top of the pipe is known as the crown.

Grade stakes and string lines or laser systems can be used to establish the proper grade during construction. String lines are established at the proper slope above the trench. Grade rods are used to check the invert elevation of each section of pipe. Laser systems shoot a beam down the inside of the pipe just above the invert of the pipe. This method is more precise than the string line method. The bell ends of the pipe must be laid upstream.

Laying Pipe to Grade

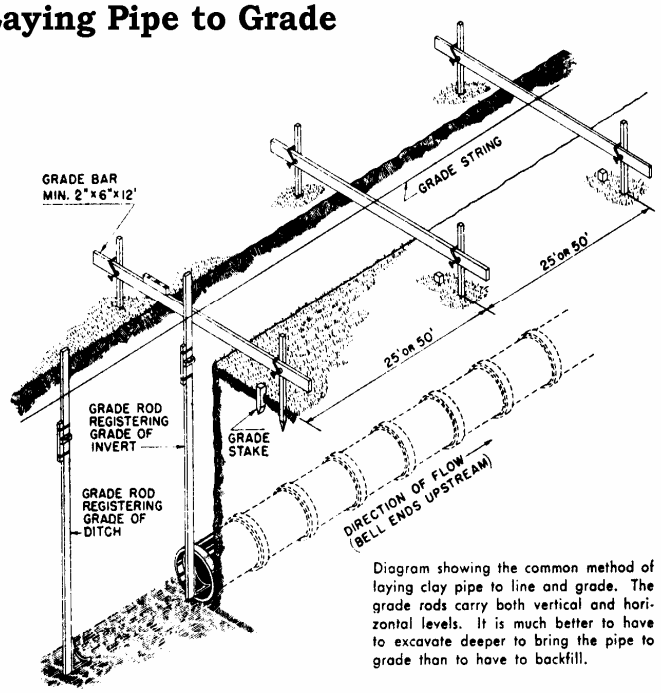
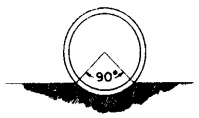
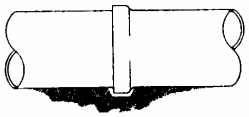


Diagram showing the common method of laying clay pipe to line and grade. The grade rods carry both vertical and horizontal levels. It is much better to have to excavate deeper to bring the pipe to grade than to have to backfill.



The lower 90 degree arc of the barrel of the pipe should be in firm contact with undisturbed earth.



Small excavations should be made for the bells. These should be no larger than necessary to clear the bell.

Once trench is excavated to the proper grade, the trench floor must be leveled. Notches are dug in the floor of the trench where the bell end of each section of pipe is located. When water lines are encountered during construction the water line should always be relocated to avoid changing the grade of the sewer line. When a sewer line crosses over a water line, the sewer line should be cast iron pipe for 50 feet on either side of the intersection. Line that must pass under roads or railroad tracks can be bored. But the line must be encased in cast iron or concrete. This maintains the proper grade and proper support of the piping.

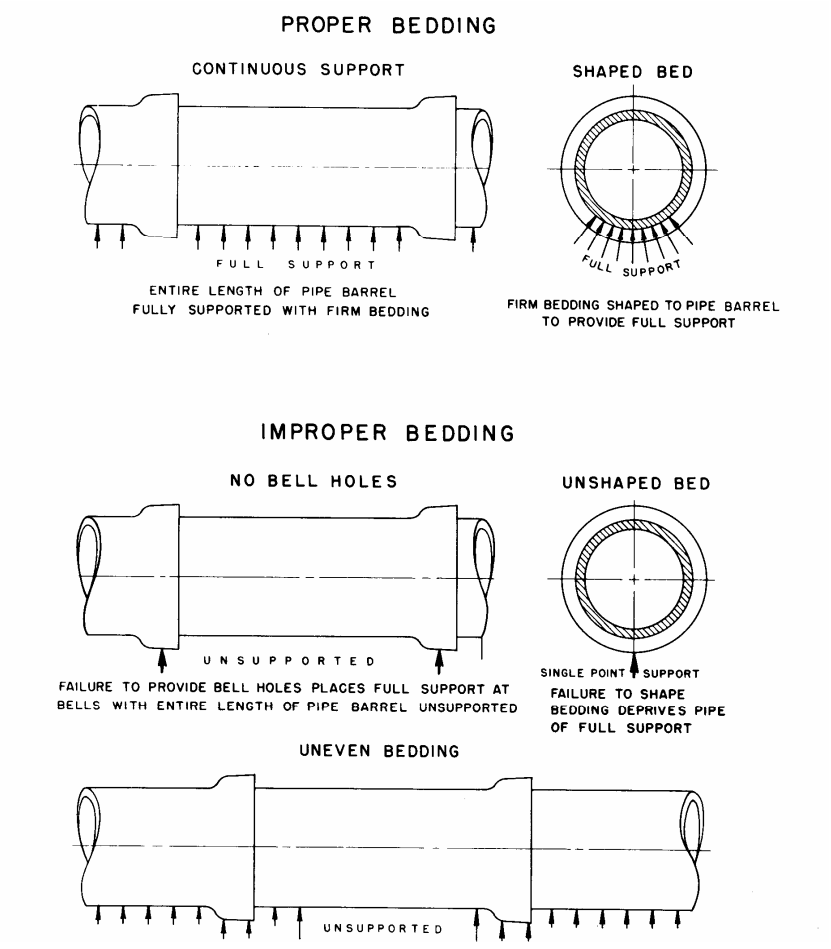
Most pipe sections have either a bell and spigot or a mortise and tenon joint. Rubber gaskets are used seal the connection. These pipe sections must be pushed together against the resistance of the gasket. When pushing pipe sections together, either by hand or with heavy equipment like a backhoe, a wooden block is placed between the bar or bucket and the pipe end. This blocking method is used to avoid damaging the pipe. Gaskets should be lubricated with grease to aid in making the connection.

BEDDING PIPING

Bedding material is used to support and protect the pipe from trench loads and pressure points. Bedding material should be free of large or sharp racks. Sand is an excellent bedding material because it compacts around the pipe well and provides excellent support. If bedding materials are not used beneath the new piping, the trench floor must be prepped to support the piping properly. The floor of the trench must be level and free of any protruding rock. Indentations must be dug under the bell ends so that they do not act as the support for the section of pipe. Improper bedding will result in broken joints that leak or collapse.

Special bedding material may be required when heavy trench loads are encountered. Class "A" bedding is concrete that is used to encase the pipe. It may be used when inverted siphons go under steams or ditches.

Class "B" and "C" bedding are granular materials like gravel or sand. They would be used for bedding plastic pipes in high load areas.

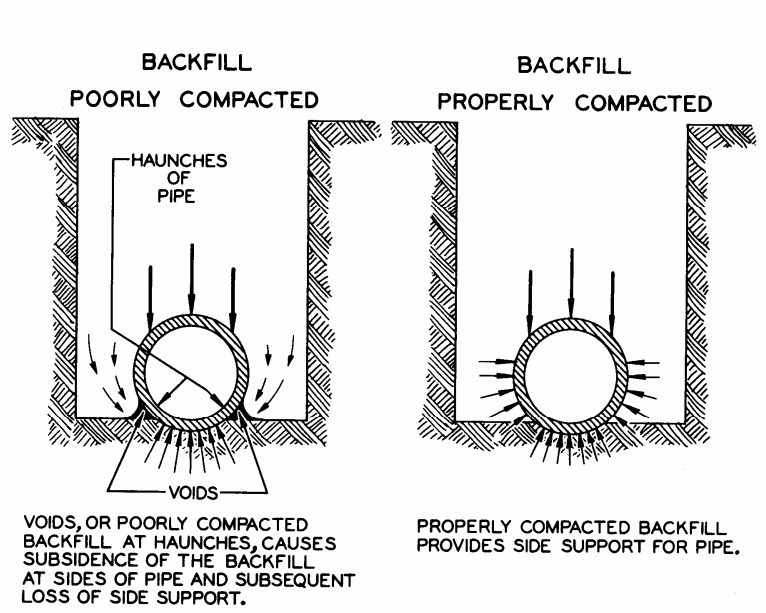


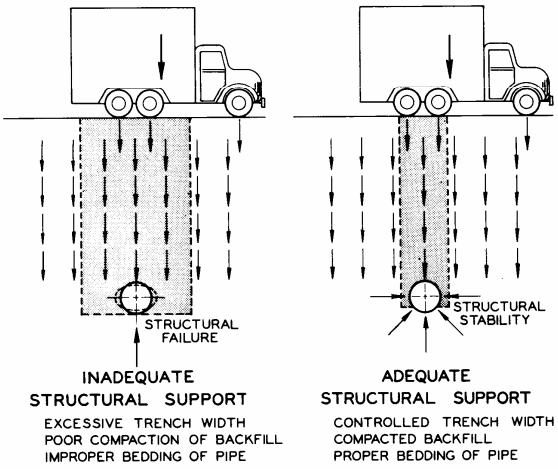
BACKFILL CONSIDERATIONS

The type of backfill material used is also a very important factor in the protection of all pipes. This is especially important when PVC pipe, with poor load bearing capability, is used. PVC piping should never be used under high load areas like highway or railroad crossings. If rocks or other abrasive material are present in the backfill, a sharp edge may create a single point of stress against the pipe wall. This can lead to misaligned or broken joints and structural collapse. To prevent this kind of damage from happening a select backfill material, preferably sand, should be used.

The backfill should be carefully added and properly tamped to help support trench loads. The backfill material should completely surround the pipe. It should be tamped when the pipe is still half exposed and again when the pipe is covered by about 6 inches of material. After the pipe is covered, backfill should be done in 12-18" lifts or layers that are tamped.

If the trench is filled completely before it is tamped, settling will occur. This will greatly increase the stress on the pipe as continuous loading from traffic occurs. This is also the reason why trenches should be cut narrow as possible. Wider trenches result in increased load stresses on the pipe.





TESTING AND INSPECTING SEWER LINES

Testing and inspection of the collection system piping is necessary to insure that new lines are installed correctly and to check existing piping for damage or corrosion. Testing may also be a means to identify sources of inflow or infiltration from broken lines or illegal connections.

TESTING SEWER LINES

There are three basic tests that are performed on sewer lines. Dye testing, pressure testing and smoke testing are done to assess the general condition of the piping. While there are other means of inspecting piping, like closed-circuit TV, these tests are relatively easy to do and can give a quick indication of the need to take a closer look with a CCTV unit.

DYE TESTING

Dye testing is used to determine if drains are connected to the sewer system. For instance, it can be poured down a patio drain, which should not be connected to the sanitary sewer, to see if the dye appears at a downstream manhole. It can also be used to estimate the velocity of the flow through a pipe. When dyes or floats are used to determine velocity in a pipe the results will normally be 10-15% faster than the actual average velocity. This is because the flow through the center of the pipe moves faster than the flow at the edges, where friction with the pipe wall is encountered.

PRESSURE TESTING

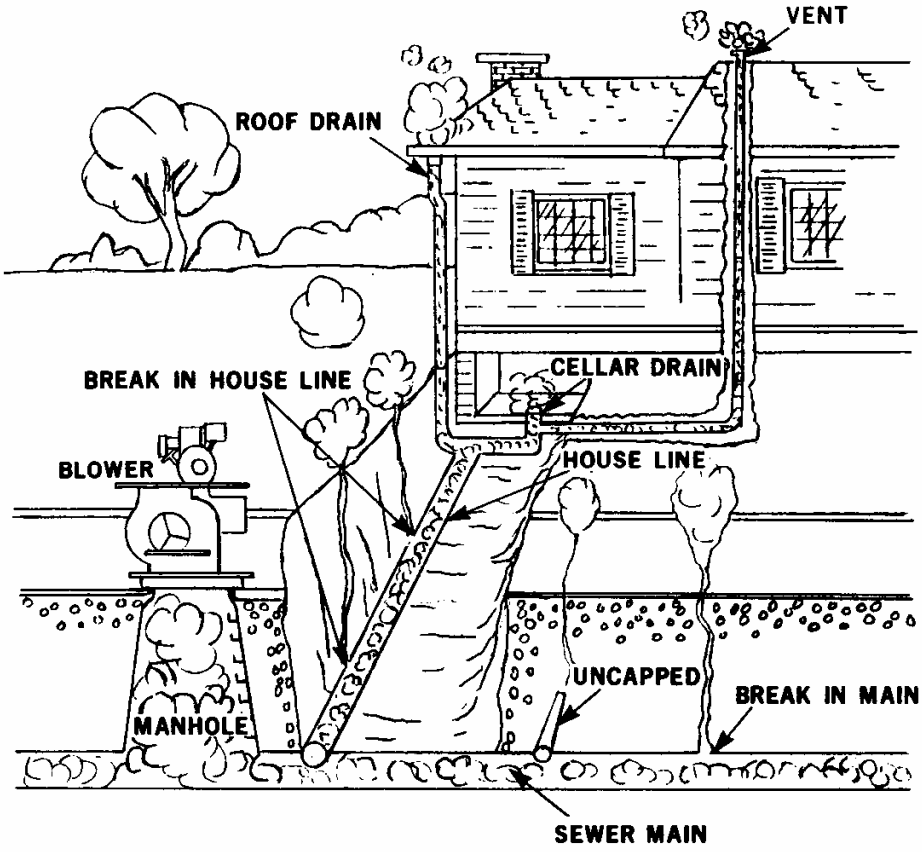
Pressure testing is usually done following new pipe installation. It may be part of the acceptance criteria for the system. If a line is not able to hold pressure infiltration from groundwater may be excessive. The line is plugged at both ends and air is pumped in until the pressure reaches 3-5 psi. When the air pressure has stabilized, the airflow is turned off. The pressure will begin to drop. The length of time it takes to drop from 3.5 psi to 2.5 psi is used to determine whether the pipe meets the criteria. A calculation is used to determine the acceptable time for the pressure drop.

Inflatable Piping Plugs

There are serious safety issues that must be addressed when using inflatable plugs in sewer lines. A great deal of force can build on the end of a pressurized plug. If it fails and blows out of the line the energy behind it can cause serious injury to anyone in the way. No one should be allowed in the manhole when one of these plugs is in the line. They are designed for insertion and removal without entry into the manhole. Anytime a manhole must be entered there are confined space safety concerns to address.

SMOKE TESTING

Smoke testing can be done on new or existing lines. A blower is used to blow smoke into a manhole and down the lines. Restrictions are placed in the pipes to "bottle" up the smoke in the areas to be tested. Traffic cones are sometimes used, since they allow flow through them while blocking most of the pipe. A blower and smoke cartridge are set up to blow air and smoke through the lines. After several minutes, the area is canvassed to identify locations where smoke is found coming up from the system.



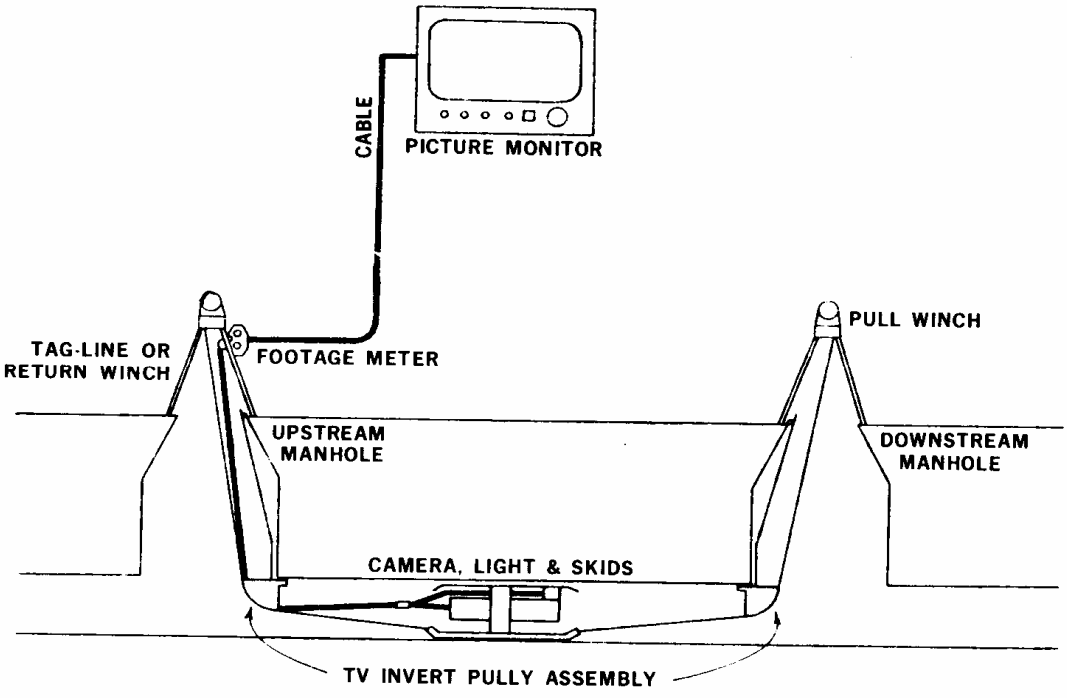
Smoke Testing

Smoke should be found coming from residential roof vents and cleanouts. If it is found from gutters or patio drains, it indicates an illegal tap. Those drains should be connected to a storm sewer. It may surface in the street or residential yards, indicating broken lines. It may come up from residential floor drains, which indicates the P-traps are dry. This situation can lead to harmful sewer gases collecting the customer's house.

Before conducting a smoke test always make sure to notify the residents, the fire department, and the police department when and where the test will take place. Smoke coming up from the basement of a house can cause panic for the homeowner and result in 911 calls. It can be embarrassing to have fire trucks respond to false alarms due to inadequate communications.

CCTV INSPECTION

A closed circuit TV unit runs a camera down the line to televise and videotape the condition of the pipe, pipe joints, grade, and service connections. It can be used to identify cracks in piping, offset or broken joints, and root intrusion while documenting the condition and location of the problem. These units consist of a truck, van or trailer that has a generator, cable spool and winch, camera unit, and video tape recorder. Older units have a winch assembly that is mounted at the end of the line and is used to pull the camera through the line. The winch on the truck was used to retrieve the camera after the inspection was completed. Newer units have a self-propelled camera that is equipped with a set of tank-like treads, or tires on larger units, that allow it to move by remote control without the need for a winch system. Some cameras have a rotating lens that can be positioned to look up into service taps on the line.



CCTV Equipment

Tracked and Wheeled Camera Systems With Rotating Camera Heads

The line should be cleaned with a jet cleaner prior to the inspection. The jet unit can also be used to string the cable for the winch systems. The camera system is designed to allow placement and retrieval of the unit without entering the manhole. Care must be taken when the unit encounters offset joints in the pipe or collapsed lines. These are places where the camera can get stuck.

PROBLEMS IDENTIFIED BY CCTV INSPECTION

CCTV inspection can be used to locate and identify a number of conditions in collection systems that can lead to stoppages. Whenever a stoppage occurs, a CCTV inspection should be conducted after it is cleared to try and identify the cause of the problem. There are several reasons why stoppages occur at certain locations. Some stoppages are caused by structural problems. Others are a result of materials in the sewage flowing in the pipe. Grease and grit can both create conditions that result in stoppages.

STRUCTURAL PROBLEMS

Taps that protrude into the line are likely to catch debris. When certain types of cleaning equipment encounter protruding taps, the line and the tools may be damaged. Misalignment of the piping is another structural problem that can be identified by CCTV inspections. Misalignment at pipe joints is usually a result of improper bedding or trench loading failures. Misalignment can be vertical or horizontal. Vertically misaligned joints are identified as a drop or jump and horizontally misaligned joints are referred to as left or right offset.

The camera can also be used to identify changes in the slope of the piping. When the depth of the water in the line changes, it indicates a change in the grade of the pipe. When the water gets deeper the invert has dropped below grade. As the depth decreases the invert is above grade. Infiltration at leaking pipe joints can also be identified by televised inspection. Infiltration from saturated soils can create hydraulic overloading of the treatment facilities. Leaking joints can be sealed with watertight grout. If they are not sealed, root intrusion will likely occur at the leaking joints. CCTV units are also used to properly locate packing equipment used to seal joints in the pipe.

ROOTS, GREASE, AND CORROSION

Root intrusion is a major concern for collection system operators. Tree roots that find their way into sewer lines through leaking joints or customers' service lines can cause chronic stoppage and backup problems. Roots must be cut to clear the line. The problem is that cutting roots is similar to pruning shrubs. If the tip of a root is cut it splits into two branches. Misaligned joints or leaking joints that allow root intrusion must be fixed. Services that allow root intrusion are an issue because it is the customer's responsibility to maintain the service line.

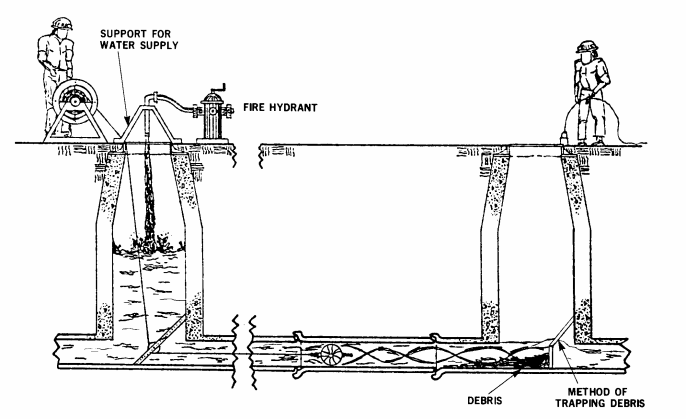
Severe Root Intrusion – Right
Grease Buildup - Bottom

Lines that carry large amounts of grease may experience clogging when it accumulates on the crown of the pipe. The result is that the carrying capacity of the pipe is greatly reduced. This restriction will cause backups during peak flow conditions.

Corrosion in sewer lines can be the result of chemicals from industrial discharges. It can also be caused by septic conditions that release hydrogen sulfide gas (H_2S). Sulfuric acid is created when the hydrogen sulfide gas reacts with the moisture on the inside of the pipe wall. This can cause serious corrosion problems in large concrete cylinder piping. It is less of an issue in vitrified clay pipe. Acids do not affect PVC pipe. Aerated lift stations and the addition of chlorine in the collection system are two ways of minimizing hydrogen sulfide production.

Crown Corrosion in a Concrete Pipe
Hydraulic Jet Cleaner in the background

BALLS AND KITES AND SCOOTERS



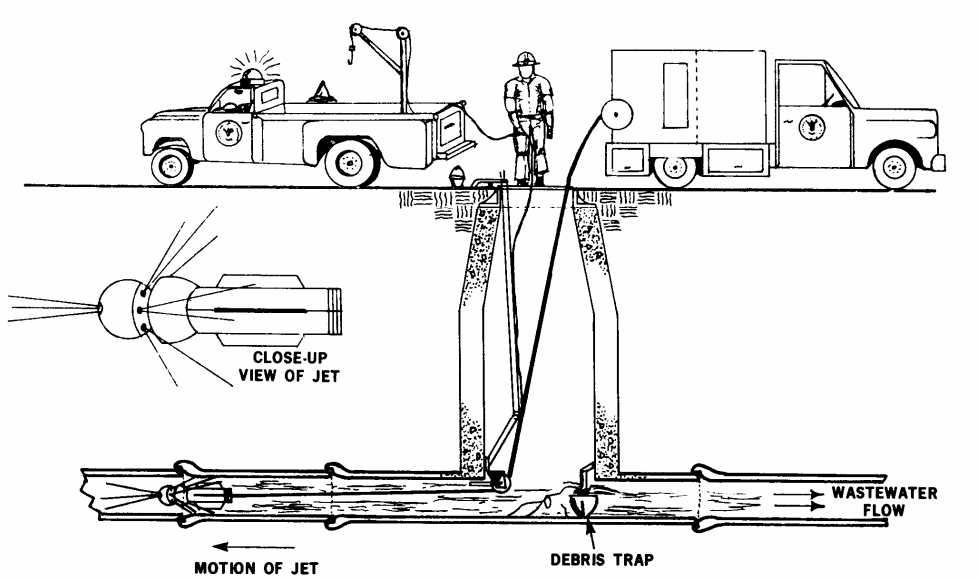
Sewer Ball Operation

Some of the first equipment designed to clean sewer lines utilized the scouring action of water passing around an object that was slightly smaller than the pipe. Head pressure was developed behind the device by adding a large volume of water upstream and creating a backup of several feet of head. The problem with doing this is that there is always a risk of flooding homes between the flushing manhole and the ball/kite/scooter. It takes a lot of water to get this process to work and it doesn't work when there is a lot of debris to move. The scooter is the most advanced tool of the group. It resembles a skateboard with a shield at one end. When debris accumulates in front of the scooter, it is pulled back 4-5 feet and the shield is dropped to allow a surge of water to push the debris on down the line.

JET CLEANERS

Hydraulic jet cleaning equipment uses a spray nozzle attached to a hose to scour debris from pipe walls and move it to a manhole where it can be removed. The unit will carry between 500-700 feet of hose on a power reel. A reciprocating positive displacement pump will supply the jet nozzle with between 60-100 gpm at 1800-2220 psi. Jet cleaning and stoppage removal operations should always run upstream to avoid the possibilities of flooding customers' floor drains and basements. The jet nozzle should always stay in motion to prevent accidentally jetting a customer's service line and causing flooding.

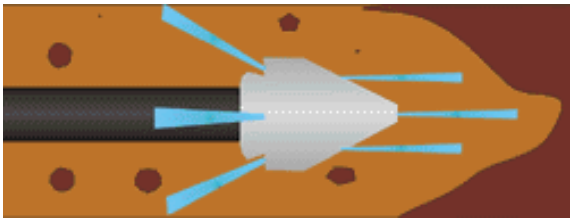
The jet nozzle is run upstream at a lower pressure (about 700 psi) until it reaches the next manhole. The upstream manhole should be removed so that a crewmember can signal the operator when the nozzle reaches the manhole. The manhole is left open during the cleaning process for ventilation. Never try to run a jet cleaner past an upstream manhole. The nozzle may come out of the line and coil in the manhole. The actual cleaning is done as the nozzle is retrieved. The pressure is increased to 2000 psi during retrieval and the jets scour the pipe and push the debris back to the manhole.

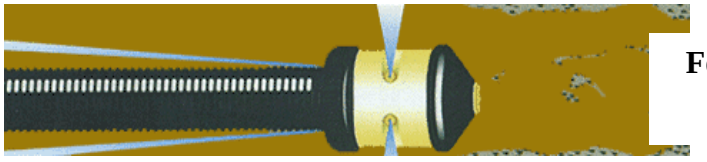


Jet Cleaner Operation

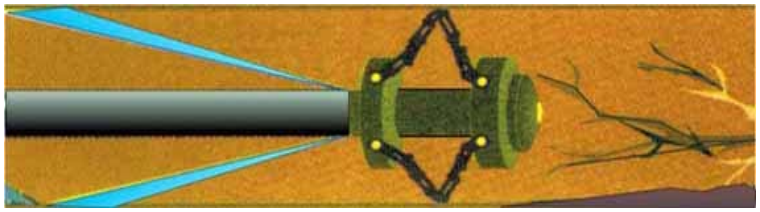
Most jet cleaners have a vacuum system to suck up the debris as it is washed back to the manhole. The debris and water are collected in a large tank. The water can be decanted back into the system and the grit is hauled to a landfill. Units that don't have vacuuming capabilities are used primarily to string CCTV cables and clear stoppages.

There are different nozzles for different applications and pipe sizes. Nozzles with forward jets are used to clear stoppages. Spinning nozzle heads are used to remove grease. Root saws and rotating chain cutters are also available for root control.





Forward Jets for Stoppages (Top)
Rotating Jets for Grease (Left)



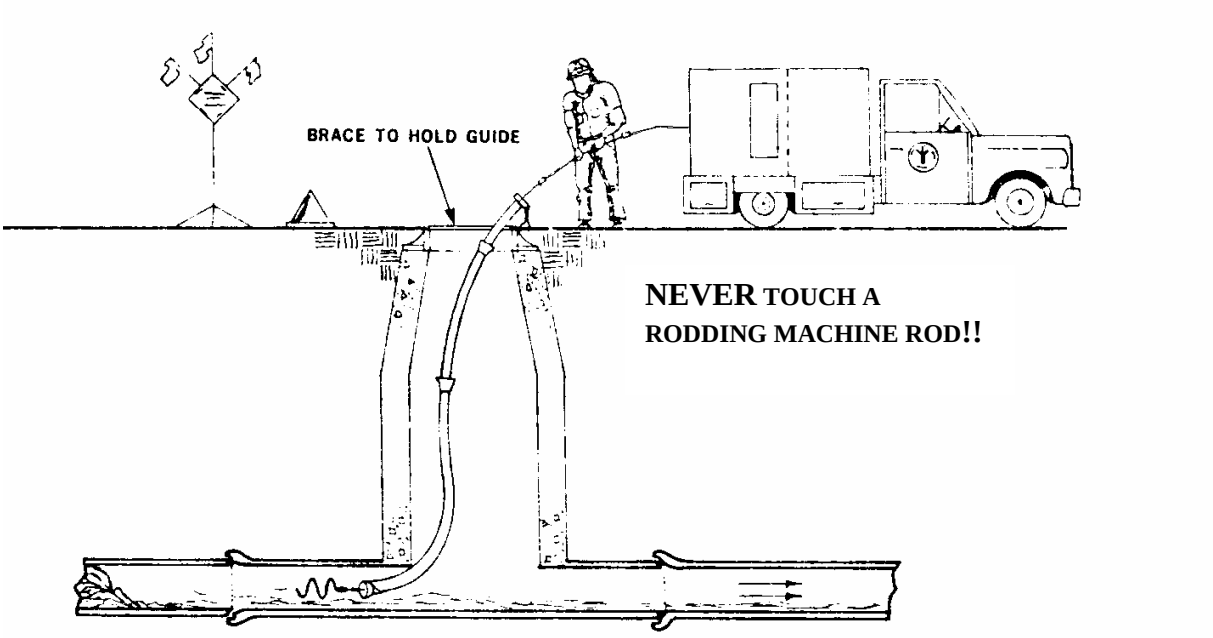
Chain-Style
Root Cutter

These units usually carry from 500-1200 gallons of water with them. They are refilled at fire hydrants. The fill line must be equipped with an air gap to prevent the possibility of a cross connection. Fire hydrants must be opened slowly to prevent water hammer. Dry barrel hydrants must be fully open to prevent jetting water through the drain hole and undercutting the pavement. If the flow is throttled it must be done through a valve attached to the hydrant nozzle while the hydrant valve remains fully open.

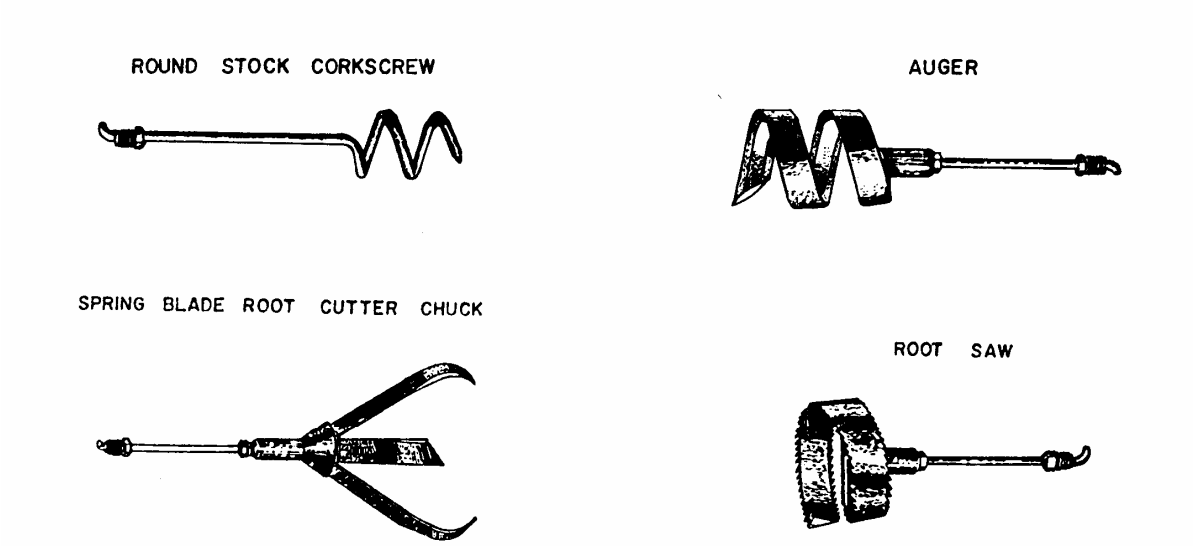
Combination Jet Cleaner
and Vacuum Truck

RODDING MACHINES

Rodding machines are used to cut roots and clear stoppages in lines. They use a long steel rod with a tool attached to the end to drill through the obstacle in the pipe. They use a variety of tools to accomplish different tasks. Root saws are used to cut roots. Porcupines are used for grease removal. Corkscrews and augers are used to attack stoppages. Like a jet cleaner, a rodding machine should attack roots and stoppages from the manhole downstream of the stoppage. This way roots and debris are carried away from the stoppage as the tool advances. It is important to know how far the tool is into line in case it gets stuck and has requires excavation. Rodding machines generate tremendous torque has they spin the rodding tools. This energy can be dangerous to anyone in the vicinity if the tool gets hung up or the rod breaks. This energy can also result in damage to piping and joints that are offset when this happens.



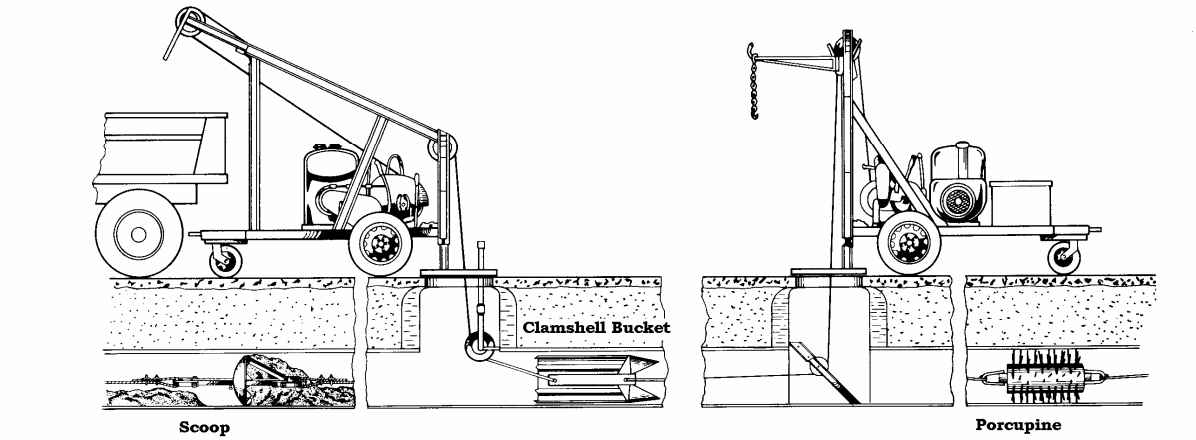
Rodding Machine Opertation



Rodding Machine Tools

BUCKET MACHINES

Bucket machines use two winches to drag a clamshell bucket or porcupine through a line to clean it. They are slow and can damage piping if they get hung up in the line on things like protruding services. Because of the energy and torque involved in the winch operation, mechanical failures can lead to serious injury to the operator. The bucket should be removed and an overnight barrel attached to the cables when a job is not completed by the end of the day.



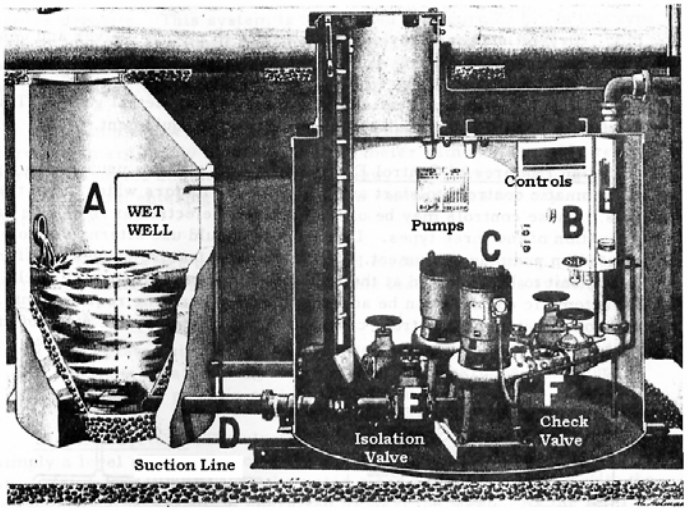
Bucket Machines

LIFT STATIONS

There is a limit to how deep you can dig with a backhoe. That limit is 30-33 feet. When a gravity sewer reaches that depth, a lift station is installed to lift the wastewater back up to a point where it begins gravity flow again. They are also used to lift the waste flow over a hill or ridge when necessary. Lift stations are built as either wet well or dry well installations.

A wet well lift station consists of a wet well to contain the incoming flow and submersible pumps in the wet well. It is cheaper to build than a dry well lift station, but maintenance can be problematic because of the grease and sewer gases that are present. The wet well is a confined space that requires special entry procedures (See Chapter 16). It can contain a hazardous atmosphere even if the top is open.

A dry well lift station has a wet well to collect the flow and a dry well for the pumps and controls. They are more expensive to build but the machinery is easier to access. The dry well is still a confined space and should not be entered without following the proper confined space entry procedures. Continuous forced ventilation is required during entry.



Dry Well Lift Station

The discharge line from the lift station is called a force main. It remains a force main until it discharges to a gravity sewer. A check valve on the discharge side of each pump prevents the flow from moving back through the pumps when they are not running.

When one of the check valves becomes fouled, the other pumps will pump longer on each cycle because the flow leaks back through the clogged check valve and recirculates back to the wet well. If the pumps alternate and one pump shows 3-4 times the running hours, the pump with the shorter run time probably has a clogged check valve that is allowing recirculation to occur. When seal water is required on a centrifugal wastewater pump, an air gap must be used to provide a physical separation for cross connection prevention.

Odor problems can occur in lift stations with long wet well detention times. Air diffusers can be installed to "freshen" the sewage. Chlorine, potassium permanganate, and hydrogen peroxide can also be used for odor control at lift stations. Pump start levels can also be lowered so that the pumps cycle more often. Cycling too often, though, can result in pump and starter problems.

Another pump operational problem arises when pumps are assigned to "Standby" mode. One of the pumps in the lift station is usually taken off-line every week. This is known as rotating the pumps. When a pump that is full of sewage sits for a week, sewer gases are released that can "air lock" the pump. If these gases are not "bled" from the pump before it is returned to service, it may overheat and burn up. This is not an issue with submersible pumps. They have a volute designed to prevent air locking. It is important to know the Net Positive Suction Head (NPSH) for the pumps. It is the minimum suction pressure needed to avoid cavitation. The stop switch for the pump must be set at least as high as the NPSH requirement.

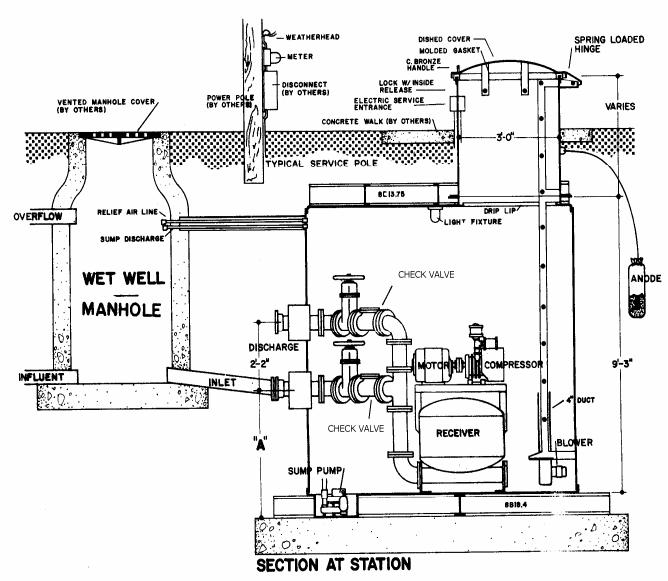
Level controls are needed to start and stop the lift station pumps. Some stations use floats as level controls. Unless they are tied off on a "Christmas tree," they can become entangled and cause wet wells to overflow or pumps to burn up. The best means of level control is the use of a pneumatic controller or air bubbler system. Air pressure in the bubbler is equal to the height of water above the end of the tube. The change in pressure as the level changes is used to control the pumps. Lift station pumps may require clean seal water for packing or mechanical seals. If the source of water is the public water supply, cross connection prevention measures must be taken. A physical separation must be maintained using an air gap

LIFT STATION PUMPS

There are four types of pumps used in lift stations. Most lift station use end suction centrifugal pumps. Very small lift stations may use ejector-style positive displacement pumps or airlift pumps. Lift stations at treatment plants, lifting water from the primary clarifiers into the activated sludge basins, may use screw pumps.

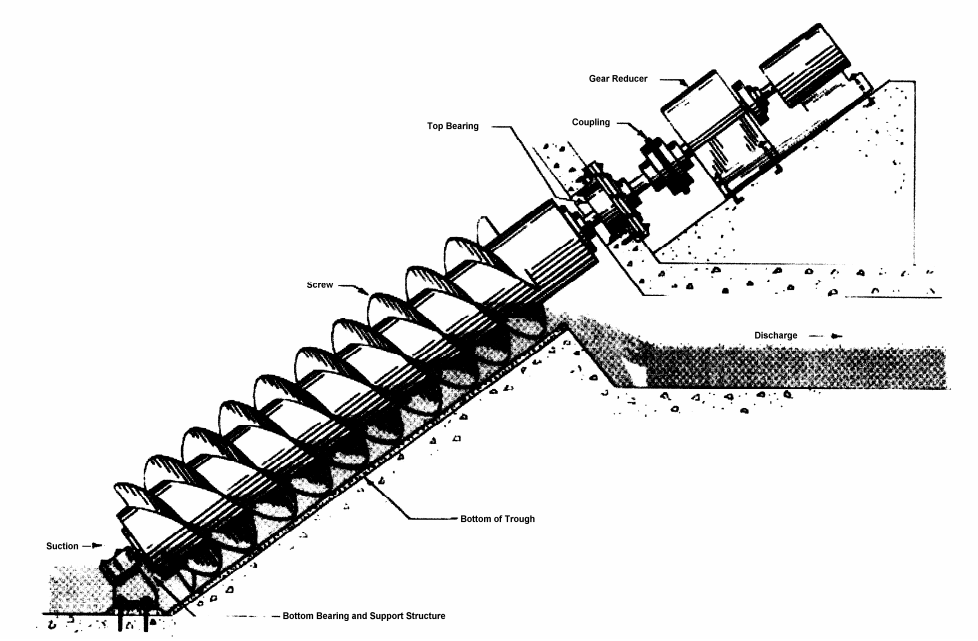
An ejector pump operates like an air-powered diaphragm pump. Water enters the receiver tank on the suction stroke as air pressure is released. The discharge occurs when a blast of pressurized air is released into the receiver. This literally blows the water out of the tank and up the force main.

Airlift pumps move water by blowing air into the bottom of a standpipe. The rising air bubbles carry water up through the pipe to discharge. An airlift pump is very inefficient and can only lift water 5-7 feet.



Ejector Pump Lift Station

Screw pumps have been used for centuries in low lift applications. They were used to lift water out of irrigation canals and into farmers' fields. The application for screw pumps in lift stations today is usually to lift water into activated sludge aeration basins. They are constant speed pumps with a variable flow capability. As the flow increases, the depth of the water at the bottom of the screw increases. The screw will pick up more water with each revolution and the discharge flow increases. The inclined screw is supported by two very large bearings at the top and bottom. These bearings require special attention to lubrication schedules due to the load they carry.



PIPING REPAIR AND REHABILITATION

While many systems contract the installation of new sewer lines to construction companies, system operators are responsible for repairs on line failures. Root intrusion can cause infiltration and pipe damage as the root system grows. Improper bedding and trench loading problems can result in misalignment and structural failures. Corrosion from hydrogen sulfide gas will degrade the crown of the pipe wall until a catastrophic failure occurs. Sometimes the piping has simply reached its normal useful life and fails from old age.

When a line break occurs, the first priority is to establish a bypass pumping operation to divert wastewater flow around the break to a downstream manhole. A pneumatic plug is inserted in the line at the manhole upstream of the break. When possible, the plug should be inserted in the upstream side of the manhole. The pump set up at the next upstream manhole and hose run to the manhole below the break.

This may not be practical if it results in a run of over 600 feet or if the hose has to cross a busy street where traffic can't be diverted. If the plug is inserted in the downstream side of the manhole care must be taken to properly secure it. If it deflates it can get pushed into the line and cause another stoppage. A plug inserted in the upstream side will pop out into the manhole when it deflates and is less likely to get drawn downstream. In either case, a pneumatic plug should always be tethered and secured.

System operators must be properly trained and equipped for line repair work because these repair jobs can be some of the most hazardous excavations that are encountered in collection systems. Once soil becomes saturated it is classified as Class C soil and requires 1½ to 1 sloping or solid sheeting for shoring. Trench boxes are also used when saturated soils become too unstable for the safe installation of shoring. An engineer must design shoring for excavations more than 14 feet deep.

PIPE REPAIRS

Misaligned or broken pipe must be removed and new pipe spliced in its place. The straight pipe ends are connected using one of several types of rubber slip couplings. These couplings can be simply rubber sleeves with radiator-style clamping bands to seal the ends. Heavier clay pipe may require an outside steel sleeve for proper support.

RUBBER SLIP COUPLINGS

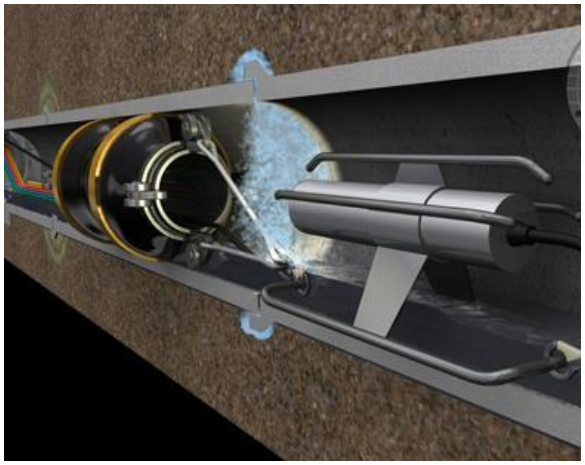
Great care must be taken to ensure that the repaired section of pipe is properly bedded and backfilled for support. If the bedding material is not properly tamped around the repair, the trench loading can cause another failure to occur. Service lines are reconnected to the pipe using a saddle tap and slip coupling.

STEEL SLEEVE SLIP COUPLINGS

CHEMICAL GROUTING

Leaking pipe joints can draw bedding material and soil from outside the pipe into the line. This heavy material can easily create stoppages far downstream of the actual leak. The loss of the support material around pipe can result in misalignment of joints or complete collapse of the line. Leaking pipe joints and joints with root intrusion may be repaired without replacement by sealing the joint with a chemical grout. The grouting process can only be used if the pipe wall integrity has not been compromised.

The chemical grout is not cement that hardens and gives support. It is a low-viscosity polymer-based liquid that can be pumped into the joint and out into the surrounding soil. As the grouting cures it congeals into a gel that binds the material outside the joint to form a watertight seal. Root inhibiting chemicals can also be mixed with the grout to prevent additional root intrusion.



POSITIONING THE PACKER UNIT

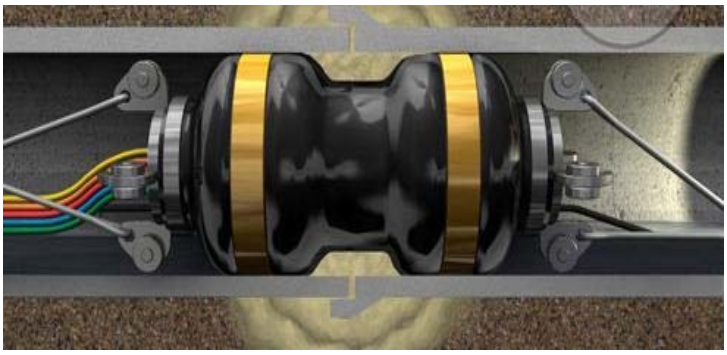
A line that is going to be grouted must first be cleaned with a jet truck. Roots must also be cut prior to the packing operation. A power winch is set up at the remote manhole. A jet truck or rodding machine is used to run a cable back to the manhole where the grouting unit is located. A CCTV camera is attached to the cable facing backwards. The grouting packer is attached to the camera. Five hoses are attached to the packer unit. Two carry grouting chemicals and the others are air lines used to inflate the three packer compartments and pressure test the grout seal.

The camera is used to center the packer unit under the joint. Once the packer is positioned the end chambers are inflated to seal the center of the unit where the grout will be injected. Once the center area is properly sealed, grouting chemicals are pumped into the void area in the center.

After the grout is pumped into the joint, the center of the packer is inflated to force the grouting chemicals into the joint and the surrounding soil.

It takes about 40-60 seconds for the grout to expand and solidify. After it has set up, the center of the packer is deflated and the seal is pressure tested. Some packing units are also capable of sealing sewer taps and lateral connections.

INFLATING THE ENDS OF THE PACKER UNIT



GROUT IS INJECTED AND THE CENTER IS PRESSURIZED

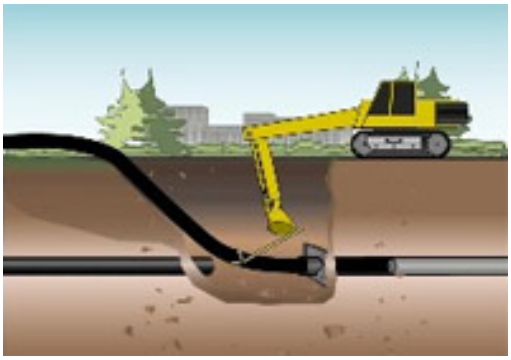
LINE REHABILITATION

Many collections systems are faced with the problem of deterioration in piping that can result in excessive infiltration, stoppages, and eventually catastrophic structural failure. Problems can also be created when flows begin to reach the carrying capacity of the line due to urban development in the area. Replacing a sewer line is a very expensive and disruptive option. There are several options available to collection systems that can rehabilitate an undersized or failing sewer line. These processes are more cost effective and much less invasive than retrenching and replacing the pipe. All of these processes involve the insertion of new flexible piping or a liner into the existing pipe to seal it.

SLIP LINING

Slip lining has been used to rehabilitate aging sewer lines for over 50 years. The process involves pulling or pushing a flexible plastic pipe through an existing line. High Density Polyethylene (HDPE) pipe, PVC pipe, and Vylon pipe are most commonly used for slip lining operations.

Another advantage of slip lining is that it requires a minimal amount of equipment and can be done by most collection systems contractors. The biggest disadvantage to slip lining is that the liner pipe is 1-2 inches smaller in diameter than the original pipe. Proponents argue that the reduced friction in the plastic liners makes up for the loss of cross-sectional area.



SLIP LINING - BACKHOE PUSHES HDPE PIPE

The line must be hydraulically cleaned prior to slip lining. It should also be CCTV inspected to make sure it is suitable for slip lining. Misaligned joints, protruding taps, or severe changes in grade may make it impossible to slip line.

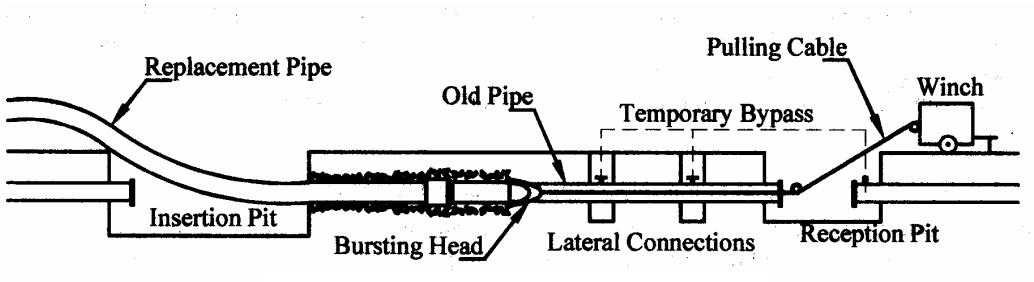
HDPE pipe segments are heat-welded together by a process known as butt fusion to form a continuous pipe that can be hundreds of feet long. The pipe can be pulled through the line with a winch or pushed with a backhoe. The PVC and Vylon pipe segments are connected with compression fittings and are pushed into the pipe using a backhoe. The only excavation is a small, sloped trench that used to guide the flexible pipe into the old line. When HDPE is used, the wastewater flow must be bypassed around the slip lining operation until the liner pipe has been completely inserted. Segmented PVC or Vylon pipe can be pushed into the pipe without need for a bypassing operation.

After the liner has been pulled through the pipe, it must sit for 24 hours before it is grouted at each end and services are reattached to the new liner. The 24-hour waiting period is necessary because the pipe has stretched from the force needed to drag it through the line. It must be allowed to shrink back to its original length first or the taps may pull loose.

PIPE BURSTING

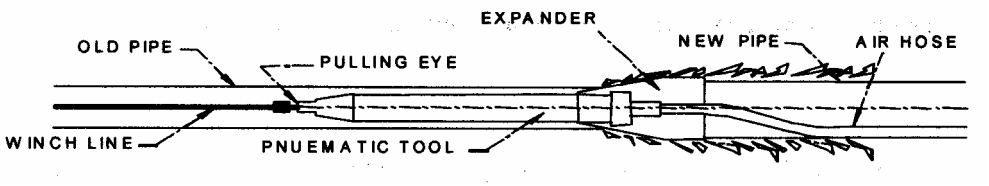
Pipe bursting is another method of slip lining. It involves breaking up the existing pipe so that a liner that is as large or larger than the existing pipe can be pulled through the expanded space. It is becoming much more popular than standard slip lining because of this ability to up-size the existing piping. It can also be used where misalignment or grade problems might make normal slip lining impossible.

An insertion pit is dug to allow placement of the bursting head and liner pipe in the existing line. A cable is attached to the bursting head and a wench draws it through the pipe. The nose of the bursting head is smaller than the existing pipe to maintain alignment and to ensure a uniform burst. The base of the bursting head is larger than the existing pipe and the liner, if it is larger than the pipe. The cable maintains a constant lateral pressure to keep the bursting head moving forward as the existing pipe wall is crushed. The liner is pulled into the pipe as the bursting head moves forward.



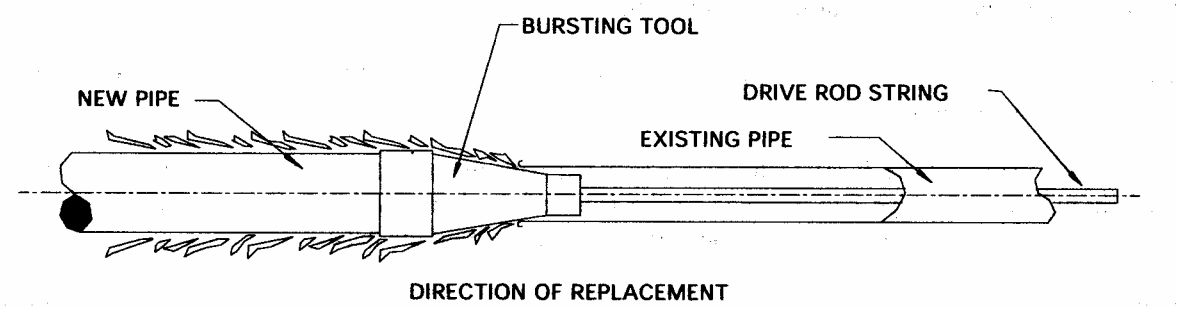
PIPE BURSTING INSTALLATION

There are three different types of pipe bursting systems. The most popular method of pipe bursting is pneumatic bursting. Pneumatic bursting systems use a pneumatic boring tool to drive the bursting head through the pipe. Pulsating air pressure acts like a battering ram to move the bursting head forward. Hydraulic expansion systems use a hydraulically operated bursting head that expands and closes sequentially crushing the pipe as it advances. This method requires more winch capacity since it takes more effort to pull the head through the pipe.



PNEUMATIC PIPE BURSTING HEAD

The third type of pipe bursting is the static pull method. Instead of using pneumatics or hydraulics to break up the pipe, it relies on the brute force of the pull winch to draw it through the pipe. It takes a tremendous amount of force to burst pipe using this technique. Even small pipes may require wenches rated at 50 tons or more.



STATIC PIPE BURSTING HEAD

CURED-IN-PLACE PIPELINING (CIPP)

Sewer lines that are still structurally sound can be lined and sealed with a flexible liner that is inserted in the pipe and then held in place until resins in the fabric harden. This process is known as cured-in-place pipelining or "in-situ" pipelining. Prior to lining, the pipe must be cleaned and inspected to determine if it is structurally suitable for the process. The resins in the liner will harden and provide some structural support, but a badly deteriorated pipe should slip lined.

The liner is a large tube of synthetic fabric webbing the same diameter as the pipe. An inflatable bladder is placed inside the fabric tube and the liner is saturated with a waterproof epoxy resin. The liner is folded flat and pulled through the pipe by a remote downstream wench. The bladder is inflated to push the liner out against the pipe wall. The liner is held in place for 30-60 minutes until the epoxy resin hardens and bonds the liner to the inside of the pipe. Hot water is circulated through the bladder in some systems. The heat can dramatically decrease the curing time for the resin.

This method of rehabilitation is used in very large diameter concrete lines and old brick sewers. It can seal them and protect them from crown corrosion caused by acid formation. An in-situ lining process only requires an excavation the size of a manhole, instead of the long pull trenches needed for slip lining. The biggest disadvantage is the special equipment and expertise required to install the lining correctly means that only a few large contracting firms will be able to do these jobs. The installation costs are therefore normally higher than with slip lining.

BASIC STUDY QUESTIONS

1. What are the components of a wastewater collection system?
2. What is the minimum velocity requirement for gravity sewers?
3. What are the two types of lift stations?
4. What is the main disadvantage of concrete sewer piping?
5. Where are manholes located?
6. Where are inverted syphons used?
7. What are the three most common types of lift station pump?

BASIC SAMPLE TEST QUESTIONS

1. Vitrified clay pipe is usually joined using:

   A. Mechanical joints
   B. Bell and Spigot joints
   C. Threaded fittings
   D. Glue

2. Sewer gases in collection systems:

   A. Represent a health hazard
   B. Can corrode concrete pipe
   C. Create odor complaints
   D. All of the above

3. The problem with sewer balls and scooters is:

   A. Flooding of upstream residences
   B. Odor complaints
   C. Equipment costs
   D. All of the above

4. The discharge line from a lift station is called a:

   A. Flow vent
   B. Return line
   C. Force main
   D. Station overflow

5. A service line should slope at least:

   A. 1/8” per foot
   B. 1/4” per foot
   C. 1/2" per foot
   D. 1” per foot

6. The crown of a pipe is:

   A. Outside top of the pipe
   B. Inside top of the pipe
   C. Inside bottom of the pipe
   D. Left side of the pipe

4. Illegal taps can be found by doing:

   A. A smoke test
   B. A pressure test
   C. A flow test

ADVANCED STUDY QUESTIONS

1. When is a drop manhole installed?

2. What should be done to control roots in the system?

3. What happens when a lift station pump check valve gets clogged?

4. What are the disadvantages of using a rodding machine?

5. How do you calculate the slope of a pipe?

6. What is the procedure for cleaning a line with a jet cleaner?

7. Under what circumstances is an engineer required to design shoring for an excavation?

8. What are the three types of pipe bursting processes?

9. What types of pipe are used for slip lining?

10. What are the disadvantages of “in-situ” pipe lining?

ADVANCED SAMPLE TEST QUESTIONS

1. When connecting a water line to a wastewater pump always install:

   A. A vacuum breaker
   B. An air gap
   C. A double check valve
   D. All of the above

2. Class "A" bedding material is:

   A. Sand
   B. Gravel
   C. Concrete
   D. Rocks

3. The best way to determine the condition of a sewer line is:

   A. A smoke test
   B. A closed circuit TV inspection
   C. A flow test
   D. A pressure test

4. The only place smoke should be seen during a smoke test is:

   A. The floor drains
   B. In the yard
   C. Roof gutters
   D. Roof vents

5. Which type of pipe is likely to have crown corrosion due to hydrogen sulfide gas?

   A. PVC
   B. VCP
   C. Concrete pipe
   D. All of the above

6. Which sewer line rehabilitation process requires the smallest excavation?

   A. CIPP process
   B. Pipe bursting
   C. Slip lining

7. Which slip lining process requires the most wench capacity?

   A. Static pull bursting
   B. Pneumatic bursting
   C. Hydraulic bursting